**CALIFORNIA DIVISION OF MINES AND GEOLOGY**
**FAULT EVALUATION REPORT FER-214**

# Honey Lake and related faults, Lassen County


by

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## INTRODUCTION

Northwest-trending right-lateral faults and north-trending normal faults cross the Honey Lake basin in southeastern Lassen County (Figure 1). These faults offset the sediments of Pleistocene Lake Lahontan and the alluvium overlying them. Scarps in late Pleistocene to Holocene deposits (Grose and others, 1990), as well as the surface rupture associated with the 1950 Fort Sage Mountains earthquake (Gianella, 1957), indicate that faults in this area are active.

Active and potentially active strands of the Honey Lake, Fort Sage, Warm Springs Valley and other unnamed faults lie within the current study area. They are evaluated here for possible zoning under the Alquist-Priolo Special Studies Zones Act (Hart, 1988). The Fort Sage fault was previously zoned under this act on the SE¼ Doyle quadrangle (CDMG, 1976).

## REVIEW OF AVAILABLE DATA

Strands of the Honey Lake fault zone form the boundary between the Sierra Nevada and Basin and Range geologic provinces (Figure 1). Other strands of the Honey Lake zone and the other faults lie within the Basin and Range province. The Diamond Mountains, on the southwestern side of the basin are a northern extension of the Sierra Nevada and have the high, steep mountain front that is typical of the Sierra Nevada. The Honey Lake and Warm Springs Valley fault zones trend northwestward across the valley. Both are thought to be strands of the Walker Lane right-lateral fault system (Bonham and Slemmons, 1968; Bonham, 1969; Pease, 1969; Grose, 1984), which is an important tectonic element of the western Basin and Range geologic province. North-trending normal faults, such as some strands of the Honey Lake fault zone, the Fort Sage Mountains fault and other unnamed faults are also typical of the Basin and Range province. The Modoc Plateau bounds the Honey Lake basin on the north.

The Honey Lake basin was filled by an arm of glacial Lake Lahontan several times in the Late Pleistocene (Morrison, 1961; Davis, 1978; Benson and Thompson, 1987). Although there is disagreement concerning the exact timing of the highstands of the lake, virtually all of the Honey Lake basin was covered by water until 12,500 years ago (Figure 2) when the high stand reached an elevation of 4,380 feet (1,335 m). Fault scarps that offset the former floor of this lake or the shorelines thus are likely to have formed during Holocene (post 11,000 year bp) time. Deposits that overlie or are incised into Lake Lahontan deposits are similarly Holocene in age.

An important constraint on the absolute ages of some Holocene deposits is provided by two widespread beds of volcanic ash. The Mazama bed and the slightly older Tsoyawata bed (Davis, 1978) were both erupted from Mt. Mazama (Crater Lake) about 7,000 years ago. The type locality of the Tsoyawata bed is in Upper Long Valley, south of the Honey Lake basin (site JOD 28, Figure 2). Anderson and Hawkins (1984) used the presence of Mazama ash in alluvium to prove Holocene offset on the Pyramid Lake fault zone (a strand of the Walker Lane).

Honey Lake fault zone

The Honey Lake fault zone was first mapped by Russell (1885) and described by Diller (1908) as a normal fault about 50 miles (80 km) long extending from near Susanville into Nevada and separating the granitic Diamond Mountains from the alluvium-filled Honey Lake basin and Long Valley. Total normal offset was estimated to be at least 2,000 feet (600 m) (Diller). Jenkins (1938), Lydon and others (1960), and Burnett and Jennings (1962) mapped this fault in more detail. Lydon and others and Burnett and Jennings show several strands of this fault offsetting Tertiary and older rocks within the Diamond Mountains as well as strands along the base of the mountains which locally offset Quaternary alluvium (Figure 1 inset). Several workers (Pease, 1969; Bonham and Slemmons, 1968) have considered the Honey Lake fault zone to be a major element of the right-lateral Walker Lane fault system.

Further mapping by Roberts (1985) and Grose and others (1990) has refined the location of faults in the Honey Lake basin. Roberts shows the northwest end of the Honey Lake fault zone along the base of the Diamond Mountains as being covered by Quaternary alluvium, but she maps one strand over a mile east of the mountain front as offsetting alluvium (locality 1, Figure 3a). Roberts noted that this fault is well defined on 1954 aerial photographs but is indistinct on later photos and in the field. She speculated that there may have been surface rupture on this fault in 1950, triggered by the Fort Sage Mountains earthquake.

Grose and others (1990) were unable to confirm the existence of a fault zone along much of the base of the Diamond Mountains to the southeast, as it was previously mapped (Figure 1). The fault is either discontinuous or is extensively covered by Quaternary deposits. Western strands of the fault first mapped by Lydon and others (1960) and Burnett and Jennings (1968) were confirmed and shown to offset bedrock and be covered by Quaternary alluvium. A strand of the Honey Lake fault zone east of the Diamond Mountains, on the floor of the Honey Lake basin was also mapped by Gross and others (1990). This right-lateral fault trends N45W, parallel to the front of the Diamond Mountains, crosses Long Valley north of Doyle and extends to the southeast along the east side of Long Valley (Figure 1). This fault offsets Lake Lahontan deposits and overlying Holocene fluvial deposits in Honey Lake basin. Wagner and others (1989) estimate that the Honey Lake fault zone has a minimum of 800m of vertical (west side up) and possibly 10km of right-lateral offset.

<u>Fort Sage fault</u>

The Fort Sage fault was originally mapped by I.C. Russell (1885) as part of his study of the Lake Lahontan region. Russell shows it on his map of "Post-Quaternary" (post Lake Lahontan) faults. It was not included on the 1938 Geologic Map of California (Jenkins, 1938), however, and was virtually unknown until the Fort Sage Mountains earthquake of December 14, 1950. The Fort Sage Mountains earthquake (M 5.6, Real and others, 1978) caused west-facing scarps up to 20cm high and monoclinal warps indicating up to 60 cm of displacement along 9 km of the fault (photo 1) (Gianella, 1957). For this reason, the Fort Sage Mountains fault was included in an Alquist-Priolo Special Studies Zone in 1976 (CDMG, 1976). This A-P zone map used the old Doyle 15' quadrangle as a base. The fault trace has been transferred to the new Doyle 7½' quadrangle for this report (Figure 3g).

<u>Warm Springs Valley fault zone</u>

The Warm Springs Valley fault zone has been mapped along the steep northeastern face of the Fort Sage Mountains by Lydon and others (1960) (Figure 1) and Grose (1984). Grose (1984) considers the fault zone to be one of the major, right-lateral faults of the Walker Lane fault system. Lydon and others (1960) show this fault along the contact between the granitic rocks of the Fort Sage Mountains and the alluvium of the Honey Lake basin (Figure 1). Grose (1984) and Grose and others (1990) show the fault along the mountain front to be covered by Quaternary alluvium (shown as Holocene by Grose and others (1990), and undifferentiated Qal by Grose (1984)).

Grose and others (1990) show several faults in Lahontan lake beds (latest Pleistocene and Holocene) along the trend of the Warm Springs Valley fault zone northwest of the end of the Fort Sage Mountains (Figure 1). These faults form a crude, left-stepping, en echelon pattern and may represent a continuation of the Warm Springs Valley fault zone.

Faults north of the Fort Sage Mountains

Grose and others (1990) mapped a set of north-trending faults that cross the Honey Lake Valley north of the Fort Sage Mountains. These faults are shown as normal faults with both down-to-the-east and down-to-the-west displacement offsetting Lahontan lake sediments.

INTERPRETATION OF AERIAL PHOTOGRAPHS AND FIELD CHECKING

Geomorphic evidence for recent faulting was interpreted from aerial photographs and plotted on 7.5-minute topographic maps (Figure 3a,b,c,d,e,f,g and h). Aerial photographs of approximately 1:20,000 and 1:30,000 scale taken by the USDA in 1954 and the USFS in 1982, respectively, were used for the entire area.

Geomorphic expression of faulting and units offset by faults were field checked on November 13-16, 1989 and June 20-22, 1990 with the assistance of G. Borchardt, CDMG soil mineralogist. Geomorphic evidence for recent faulting was noted and the degree of weathering or soil development was examined at several locations where evidence for or against Holocene offset was expected to be particularly clear, based on the aerial photographs. Soil descriptions are included in Appendix A. Shorelines of glacial Lake Lahontan and beds of volcanic ash were also noted because these features provide a means of checking the ages of offset units or surfaces.

Honey Lake fault zone

Several strands of the Honey Lake fault zone were verified by aerial photo interpretation and field work. They are described below. Normal faults along the front of the Diamond Mountains are described first from southeast to northwest. The principal right-lateral strand of the fault is then described, also from southeast to northwest.

Normal faults along the front of the Diamond Mountains form scarps and faceted spurs from south of Constantia (Figure 3h) northward to near Doyle (Figure 3g). Increased incision of many streams on the up-thrown side of the fault and sharp faceted spurs suggest that this fault is recently active, although some of these features may have been enhanced by Lake Lahontan shorelines or lateral erosion. A scarp in a stream terrace of probable Holocene age at locality 2 (Figure 3h), and a steep (19°) scarp in older alluvium at locality 3 (Figure 3h) suggest that the most recent offset on this fault occurred in Holocene time.

Evidence for Holocene faulting along the base of the Diamond Mountains was not observed between Doyle (Figure 3g) and the Bird Hills (Figure 3f). Springs and tonal lineaments in bedrock (suggesting ground water barriers) define faults at locality 4 (Figure 3f). Geomorphic features along this fault to the north are a broad linear drainage, saddle, and tonal lineaments in older alluvium and bedrock. The geomorphic features appear to be erosionally degraded compared to similar features in late Pleistocene deposits, suggesting that the faults have not moved in Holocene time.

North of the Bird Hills, evidence for Holocene or late Quaternary faulting along the front of the Diamond Mountains is obscured by prominent shoreline features. These shorelines were probably formed during the last high stand of Lake Lahontan, about 12,500 years ago. No faults were observed offsetting these shorelines along much of the mountain front. One normal fault near Buntingville (Figure 3a and 3b) does offset these shorelines, suggesting that uplift is still occurring in this part of the Diamond Mountains.

The principal, active strand of the Honey Lake fault zone is well defined, linear and trends N45°W across Long Valley and the Honey Lake basin (Figures 3c, 3d, 3f, 3g, and 3h). It was first mapped by Grose and others (1990) and largely confirmed by aerial photo interpretation (Figure 1). This strand has abundant evidence for Holocene right-lateral offset, and will be described from southeast to northwest.

Along the southwest margin of the Fort Sage Mountains, the Honey Lake fault offsets young alluvial fans (Figures 3g and 3h). These fans are considered to be of Holocene age based on their youthful-appearing constructional surfaces and very weak soil development. Scarps up to 2 meters high with slopes of up to 13° were observed in this unconsolidated sandy alluvium, suggesting that offset has occurred along this segment of the fault zone in Holocene time.

North of Doyle (Figure 3g) the fault crosses a broad, gently northward-sloping surface underlain by latest Pleistocene to Holocene sandy alluvium. This material overlies lake beds east of Doyle (locality 5, Figure 3g) that were probably deposited in the last high stand of Lake Lahontan. The sandy alluvium was probably deposited as the delta and floodplain of Long Valley

Creek prograded over the area. Soil development on this surface (described at locality 7, Figure 3g) is surprisingly weak, there being little more than slight oxidation in the upper 90 cm (see description of the upper terrace soil, Appendix A). The alluvium is a uniform medium sand containing so little clay that soil structures cannot form nor illuviation occur. Uniform sands of this type are no longer being deposited by the creek, suggesting that they were deposited at the end of the Pleistocene, possibly from glacial meltwater.

The fault has formed linear, northeast- and southwest-facing scarps and tonal lineaments across this alluvial surface. The scarp reaches a maximum height of 6 m at locality 6 (Figure 3f) where the fault makes a small right step and bounds one side of a small closed depression. Most commonly, scarps are 1 to 2 m high and slope about 10° to the west.

As Lake Lahontan receded during the early Holocene, Long Valley Creek incised into the sandy floodplain and lake sediments. About three meters of fine to coarse, thinly bedded Holocene alluvium now forms an inset terrace on the north bank of Long Valley Creek at a locality where the Honey Lake fault zone crosses Long Valley Creek (locality 7, Figure 3g). The fault has offset the upper alluvial surface 3.4 m vertically and the channel margin 16±2 m right laterally (Figure 4). A smaller (about 1.2 m high) scarp crosses the inset Holocene terrace. A sketch map (Figure 4) shows these features.

Two profiles of this ancient channel margin (terrace riser) were measured and tc (time multiplied by a diffusivity constant) was calculated for each using the SLOPEAGE program developed by Nash (1984, 1987). This program fits a curve to the existing scarp profile given a few assumed initial conditions (chiefly the initial slope angle). If the diffusivity constant (c) is the same for similar materials in similar climates, it is sometimes possible to use published value of c to determine the time (t) since a scarp formed.

Widely different values of tc were calculated for two profiles of the terrace riser, indicating that some complication is preventing an accurate calculation of tc. One potential problem is erosion by slopewash, a process that cannot be modelled by a diffusion equation (Nash, 1987). Another problem may be lateral erosion or deposition. Although no age of the channel margin could be derived from the profile, the age is well constrained by the post-Lahontan alluvium forming the upper alluvial surface and mid-Holocene alluvium forming the lower inset terrace.

The alluvium constituting the lower terrace is exposed in the modern cutbank of the creek (Figure 4, Figure 5). This alluvium includes a bed of volcanic ash near its base (Figure 4). This ash resembles the ash erupted from Mt. Mazama 7,000 years ago according to G. Borchardt. The refraction index of the glass, slightly over 1.500, and the presence of hornblende phenocrysts are also consistent with the published characteristics of Mazama ash (Wilcox, 1965; Davis, 1978). Trace element chemical analysis of this ash by A. Sarna-Wojcicki of the U.S.G.S. indicates that this ash corresponds to the 7,000 year old Tsoyawata ash eruption of Mt. Mazama with a similarity coefficient of .99.

About 30 meters west of the volcanic ash outcrops, the Holocene alluvium is offset by the Honey Lake fault. Six strands of the fault displace these layers vertically about 1.2 m (down to the west) (Figure 5). Lack of correspondence of some soil units across some fault strands and thickness changes of other units across the faults suggest significant strike slip offset.

Displacement of different Holocene alluvial units and soil horizons allow a preliminary interpretation of the paleoseismology of the Honey Lake fault zone. A minimum of four earthquakes are recorded in these late Holocene sediments (Figure 5). The first of these events caused displacement on fault F6 (Figure 5) and liquefaction of the sandy sedimentary layers 9, 10 and 11 (layers are numbered from top to bottom at the point in the exposure where the most layers are exposed). A subsequent earthquake caused displacement on fault F4 and possibly warping of the section immediately to the east of that fault. The next earthquake that can be clearly interpreted from the exposure caused displacement on fault F2 of all layers except the modern soil. The last earthquake caused displacement on fault F3 of all layers including the modern soil and probably occurred within the past few hundred years.

A more detailed history of the earthquake recorded in the bank of Long Valley Creek using pedochronological estimates of the ages of soils, as well as an attempt to date small charcoal fragments and pedogenic carbonate by $^{14}C$ is in progress. Estimates of the ages of soils is included with the soil descriptions in Appendix A.

This site yields a considerable amount of information about the Honey Lake fault. To summarize; a channel margin cut into post-12,500 year bp alluvium is right-laterally offset 16 $\pm$ 2 m. A terrace deposited within the channel includes 7,000 year b.p. Tsoyawata ash. The channel is therefore between 12,500 and 7,000 years old. Slip rates calculated from 16 $\pm$ 2 m of right-lateral slip in 7,000 to 12,500 years range from 1.1 to 2.6 mm/year. The average of these slip rates is 1.8 mm/year. Earthquakes have occurred repeatedly in late Holocene time, the latest one being in the past few hundred years.

Geomorphic expression of the fault northwest of this locality includes the 6 m high scarp described above (locality 6), tonal lineaments in plowed fields (locality 8, Figure 3f) and a rhombic sag pond (locality 9, Figure 3f). Further to the northwest, on Figure 3d, the west facing scarp that marks the main fault trace has been somewhat modified by lateral erosion and other traces may exist to the southwest.

Scarps in late Pleistocene alluvium along Long Valley Creek in Sections 10 and 15, T26N, R16E were mapped as faults by Grose and others (1990) (Figure 3f). Their position along the stream, and the lack of expression on the older alluvial surface away from the stream suggest that they are stream terrace risers, not fault features.

To the north the Honey Lake fault trends slightly more northerly at the edge of Honey Lake, controlling the location of the shoreline for a short distance in section 1 T26N R15E (Figure 3d). It then trends northwestward across Honey Lake. Traces of the Honey Lake fault zone cross two peninsulas on the southwest side of "The Island" (Figure 3c); where the fault is more than 1 km wide.

The fault is exposed in a wave cut cliff on the northwestern side of the southern peninsula (locality 10, Figure 3c). There, late Tertiary (?) lake beds are intensely deformed and faulted. These lake beds contain two ash beds that were sampled and sent to A. Sarna-Wojcicki for trace element analysis and correlation. Trace element analysis of these samples suggests that they are Pliocene ashes but no positive correlation could be made.

At the fault, the lake beds are intensely folded, sheared, and brecciated. A loose gray sand has filled an irregular space along the fault zone, possibly injected as a sand layer liquefied during an earthquake (Photo 2). The deformed lake beds are unconformably overlain by a flat-lying sandy layer, probably deposited in the last high stand of Lake Lahontan. The base of this deposit is vertically offset about 6 meters (north side down). The ground surface above the wave-cut cliff and across the peninsula is vertically offset 2 meters, probably representing offset since Lake Lahontan time. Another fault 1 km to the south also is exposed as a scarp in the latest Pleistocene lake beds and can be traced southeastward in the bed of Honey Lake using USDA (1954) air photos.

Farther to the northwest, a strand of the Honey Lake fault zone is expressed as tonal features in the lake bed and a complex zone of scarps across another peninsula (locality 11, Figure 3c). The Honey Lake fault zone then continues northwestward under Honey Lake and may be continuous with faults north of Honey Lake.

A strand of the fault at the northwest end of Honey Lake is expressed as a very sharp tonal lineament and broad, low northeast-facing slope across a bend in the Buntingville - Standish road on 1954 aerial photos (locality 1, Figure 3a). This area is below the shorelines of Lake Lahontan and any geomorphic expression of the fault at this location probably formed in Holocene time after the lake receded. Roberts (1985) speculates that this fault moved in 1950 in response to the Fort Sage Mountains earthquake. The fault mapped by Roberts is very sharply defined because it forms a tonal lineament, possibly a groundwater barrier. It may be well expressed only when the groundwater is at certain levels. Its poor definition on later aerial photos and in the field does not necessarily indicate ground rupture shortly before the tonal lineament appeared. It may only indicate that the water table was at a certain level. This site was visited by this writer and W.A. Bryant on June 5, 1989. A subtle northeast facing slope in plowed fields south of the road was the only observed expression of the fault.

Two sites farther to the northwest were visited by this writer and G. Borchardt on November 16, 1989 (locality 12, Figure 3a). At two road crossings of the fault, the alluvial fan surface, which rises in elevation to the north, abruptly levels off. A slight back-facing scarp and side-hill trough are present at the eastern road crossing.

About 1000 feet to the east of this road a stream crosses the fault. Upstream of the fault, the stream follows several entrenched meanders. Downstream it has incised a relatively straight channel. Apparently the fault has displaced the ground surface upward on the southwest, locally decreasing the gradient of the stream and causing it to meander.

The fault is exposed in the east bank of the stream. Coarse, cobbley alluvium with weak soil development to the south is faulted against silty and sandy alluvium with deep red color (7.5 YR range) and thick clay films. A shear within the fault zone strikes N70°W and dips 52° SW. Striae have a southeastward rake of about 40°, consistent with oblique right slip with the south side moving up relative to the north. Many other shears form a zone 10 to 20 cm wide, but these could not be measured without much more time and careful excavation.

Fort Sage fault

The trace of the Fort Sage fault mapped by Gianella (1957) after the 1950 earthquake was largely confirmed by aerial photo interpretation and limited field checking. The 1950 surface rupture was not distinguishable on the 1954 USDA air photos, nor was any trace of the surface rupture found in two brief field checks in June and November, 1989. The trace mapped by Gianella (1957) is defined by somewhat degraded scarps that are the results of many earthquakes. On the northern third of the fault a granitic bedrock scarp rises about 25 m above the alluvial fans. The scarp has been incised by many minor drainages but maintained its linear base. To the south, west-facing scarps in alluvium define the fault. One of these was field checked (locality 13, Figure 3g). It is a west-facing scarp in older alluvium at least 8 m high.

It appears that some of the traces of the Fort Sage fault on the Special Studies Zones Map of the SE 1/4 Doyle quadrangle (CDMG, 1976) are slightly mislocated. Parts of these traces do not coincide with the trace mapped by Gianella (1957) or with any clearly fault-related geomorphology. This apparently occurred when Gianella's published fault trace was transferred to an enlarged Doyle 15' quadrangle for the original Special Studies Zones Map (CDMG, 1976). The northern portion of the fault was plotted up to 200' west of Gianella's trace. Gianella's original fault trace has now been more carefully transferred to an enlarged Doyle 15' quadrangle and traced onto the Doyle 7 1/2' quadrangle (Figure 3g). The difference between this trace and the trace based of interpretation of aerial photos is generally very small (less than 100 feet). At one location (locality 14, Figure 3g) both the CDMG (1976) and Gianella (1957) traces plot within the bedrock of the Fort Sage Mountains. The fault is well defined just to the west at the bedrock-alluvium contact. This appears to be the only location where Gianella's trace is significantly mislocated.

Warm Springs Valley fault zone

The Warm Springs Valley fault zone presumably defines the steep northeast face of the Fort Sage Mountains, a smooth granite escarpment about 60 to 300 m high. The highest shorelines of Lake Lahontan are found along the base of this escarpment. The alluvial and colluvial slope to the northeast is marked by additional shorelines. No offsets of any of these latest Pleistocene shorelines was found along the base of the Fort Sage Mountains, indicating that this part of the Warm Springs Valley fault has not significantly offset the ground surface in Holocene time.

North and Northwest of the Fort Sage Mountains, a series of faults offset the floor of the Honey Lake basin (Figure 1, 3d, 3e). One set of faults trends about N30°W and forms a set of left-stepping en echelon scarps, suggesting a right lateral sense of displacement (locality 15, Figure 3e). The height of each west-facing scarp decreases as the adjacent one increases. Two of these scarps were field checked, both were about 3 m high and had maximum slopes of about 6°. These scarps probably formed in Holocene time because they offset the floor of Lake Lahontan, a surface that was deposited only 12,500 to 15,000 years ago.

Similar left-stepping scarps occur along a N45°W trend through the town of Herlong (Figure 1, 3c, 3d, 3e). The largest of these, northwest of Herlong, is about 5 m high. Its steepest slope is also about 6°. Additional faults along this trend may partly control the northern shoreline of "The Island", a peninsula in Honey Lake. Although these faults form prominent tonal lineaments on aerial photos, they are not always obvious on the ground. A search for the geomorphic feature at locality 16 (Figure 3d) was unsuccessful. A very broad gentle scarp, partly modified by lateral erosion, was the only topographic feature observed. Despite the lack of clear geomorphic expression, the sharp tonal lineament and the slight offset of a latest Pleistocene alluvial surface suggest that these faults are Holocene active.

<u>Faults north of the Fort Sage Mountains</u>

A series of north-trending faults along the Nevada border has been mapped by Grose and others (1990). These faults form clear tonal lineaments on aerial photos but are not obvious in the field (Figure 3e). They are generally defined by sharp tonal features and broad scarps in the late Pleistocene lake sediments. It seems likely that the relatively plastic lake sediments form monoclinal warps rather than sharp scarps. Nevertheless, displacement of the originally horizontal late Pleistocene lake bed across these features suggests Holocene fault movement.

## SEISMICITY

The Honey Lake basin has a history of moderate earthquakes beginning with the magnitude 5.8 earthquake of January 24, 1875, which cracked walls in Susanville and destroyed a chimney in Janesville. Similar earthquakes caused damage at Susanville and Janesville on January 31, 1885 and at Susanville and Eagle Creek (to the north) on June 20, 1889 (Toppozada and others, 1981).

The Fort Sage Mountains earthquake of December 14, 1950 (M 5.6) is the most severe earthquake recorded instrumentally and was associated with 9 km of ground rupture as described above (Gianella, 1957). A similar earthquake (M 5.6) occurred on

February 22, 1979 near Doyle (Bryant, 1979), but no surface rupture was reported.

## CONCLUSIONS

Faults of the Honey Lake, Fort Sage Mountains and Warm Springs Valley fault zones are active and should be zoned for special studies. The Honey Lake and Warm Springs Valley fault zones are both right-lateral strands of the Walker Lane. The Fort Sage Mountains and other north-trending faults are normal faults related to basin-and-range extension. Strands of all of these fault zones have evidence of Holocene activity. Faults considered to be active are highlighted in yellow on Figures 3a, 3b, 3c, 3d, 3e, 3f, 3g, and 3h.

### Honey Lake fault zone

The Honey Lake fault zone is the northwesternmost of the right-lateral faults of the Walker Lane. It extends for over 30 km across the floor of the Honey Lake basin, parallel to the front of the Diamond Mountains. It probably extends an additional 20 km beneath Honey Lake to connect with similar active faults near Buntingville. Total horizontal displacement across the zone since Tertiary time may be as much as 10 km. Vertical displacement has been at least 800 m (Wagner and others, 1989).

The normal fault along the front of the Diamond Mountains originally mapped by Diller (1908) has been active at its southeastern end near Constantia (Figure 3h) and its northwestern end near Buntingville (Figures 3a and 3b). The majority of this strand of the fault is covered by latest Pliestocene shoreline features and deposits and does not appear to have been active in Holocene time. Other parallel faults within the mountains (Burnett and Jennings, 1962; Lydon and others, 1960; Jennings, 1975) do not have evidence for Holocene activity (Figure 1). The right-lateral strand of the fault, first mapped by Grose and others (1990) is well defined and has abundant evidence of Holocene activity. This evidence includes scarps in Holocene alluvial fans (Figure 3g), a sag pond in a latest Pleistocene to Holocene flood plain deposits (locality 9, Figure 3f), and offset Holocene deposits at locality 7 (Figure 3g). At the latter site, a right-laterally offset channel margin (terrace riser), dated as 7,000 ybp to 12,500 ybp is offset $16\pm2$ meters. A slip rate of 1.1 to 2.6 mm/yr is calculated for Locality 7. Exposure of the fault zone in the Holocene alluvium indicates that repeated earthquakes have occurred in late Holocene time.

Fort Sage fault

The Fort Sage fault is a north trending normal fault that extends about 10 km from the Honey Lake fault zone near Doyle to the Warm Springs Valley fault zone near Turtle Mountain. A M5.6 earthquake in 1950 caused surface rupture along the Fort Sage fault. Gianella (1957) measured displacement of up to 20 cm, down to the west. The trace of the fault was included within a Special Studies Zone in 1976 (CDMG 1976). The trace has been relocated on the Doyle 7½' quadrangle (Figure 3g) and confirmed by aerial photo interpretation. Most of the fault is defined by recent, west-facing scarps in granitic bedrock and alluvium, although evidence of the 1950 ruptures is largely gone.

Warm Springs Valley fault zone

The Warm Springs Valley fault zone is a major right-lateral strand of the Walker Lane which extends from "The Island" in Honey Lake 65 km southeast to Warm Springs Valley in Nevada (Lydon and others, 1960; Bonham, 1969; Grose, 1984). In California it is defined by the steep northeastern escarpment of the Fort Sage Mountains, but no recently active faults were observed along this mountain front. Lake Lahontan shorelines have covered or removed evidence for late Pleistocene faults scarps and, apparently, no Holocene scarps have formed. Several faults northwest of the Fort Sage Mountains may be related to the Warm Springs Valley fault zone and have been active in Holocene time. These form two sets of left-stepping en echelon faults; one which trends about N45°W through Herlong (Figure 3d) and another to the east trending about N30°W (Figure 3e). These zones of Holocene en echelon faults suggest Holocene right-lateral displacement.

Faults north of the Fort Sage Mountains

A set of north-trending normal faults parallels the Nevada border north of the Fort Sage Mountains (Figure 3g). These faults form low, rounded scarps in very late Pleistocene Lake Lahontan deposits. Offset of the lake bed suggests that these faults have had Holocene offset.

RECOMMENDATIONS

Traces of the Honey Lake, Fort Sage, Warm Springs Valley fault zones and other unnamed faults, highlighted in yellow on Figure 3a, 3b, 3c, 3d, 3e, 3f, 3g and 3h, appear to be sufficiently active and well defined and should be zoned for special studies under the Alquist-Priolo Special Studies Zones Act. References on the Standish 7½' quadrangle should be Roberts (1980) and this report. On the Stony Ridge, Milford, Herlong, Calneva Lake, and McKesick Peak quadrangles references should be

Grose and others (1990) and this report. On the Doyle quadrangle references should be Grose and others (1990), Gianella (1957), and this report. The reference on the Constantia quadrangle should be this report.

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Reviewed & approved.
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## REFERENCES


Anderson, L.W., and Hawkins, F.F., 1984, Recurrent Holocene strike-slip displacement on the Pyramid Lake fault zone, western Nevada: Geology, v. 12, p. 681 to 684.

Bonham, H.F., 1969, Geology and mineral deposits of Washoe and Storey Counties, Nevada: Nevada Bureau of Mines Bulletin 70, 140 p.

Bonham, H.F., and Slemmons, D.B., 1968, Faulting associated with the northern part of the Walker Lane: Geological Society of America Special Paper 101, p. 290.

Benson, L.V., and Thompson, R.S., 1987, Lake-level variation in the Lahontan Basin for the past 50,000 years: Quaternary Research, v. 28, p. 69-85.

Bryant, W.A., 1979, Earthquakes near Honey Lake, Lassen County, California: California Geology, v. 32, no. 5, p. 106 -109.

Burnett, J.L., and Jennings, C.W., 1962, Chico Sheet: California Division of Mines and Geology Geologic Map of California scale 1:250,000.

California Division of Mines and Geology, 1976, Official Map of Special Studies Zones, SE 1/4 Doyle Quadrangle, scale 1:24,000.

Davis, J.O., 1978, Quaternary Tephrochronology of the Lake Lahontan area, Nevada and California: Nevada Archeological Survey Research Paper No. 7, 137 p.

Diller, J.S., 1908, Geology of the Taylorsville Region, California: U.S. Geological Survey Bulletin 353, 128 p.

Gianella, V.P., 1957, Earthquake and faulting, Fort Sage Mountains, California, December 1950: Bulletin of the Seismological Society of America, v. 47, no. 3, p. 173-177.

Grose, T.L.T., 1984, Geologic Map of the State Line Peak Quadrangle, Nevada - California: Nevada Bureau of Mines and Geology Map 82, scale 1:24,000.

Grose, T.L.T., Saucedo, G.J., and Wagner, D.L., 1990, Geologic Map of the Susanville 1:100,000 scale quadrangle: California Division of Mines and Geology Open File Report (in progress).

Hart, E.W., 1988, Fault-rupture hazard zones in California: Division of Mines and Geology Special Publication 42, 24 p.

Jenkins, O.P., 1938, Geologic Map of California: California Division of Mines, scale 1:500,000.

Jennings, C.W., 1975, Fault Map of California: California Division of Mines and Geology Geologic Data Map 1, scale 1:750,000.

Lydon, D.A., Gay, T.E., Jr., and Jennings, C.W., 1960, Westwood Sheet: California Division of Mines Geologic Map of California, scale 1:250,000.

Nash, D.B., 1987, SLOPEAGE: a computer program for morphologic dating of scarps: University of Cincinnati, Ohio, Department of Geology.

Nash, D.B., 1989, Morphologic dating of fluvial terrace scarps and fault scarps near West Yellowstone, Montana: Geological Society of America Bulletin, v. 95, p. 1413-1424.

Pease, R.W., 1969, Normal faulting and lateral shear in northeastern California, Geological Society of America Bulletin, v. 80, p. 715-720.

Real, C.R., Toppozada, T.R., and Parke, D.L., 1978, Earthquake epicenter map of California: California Division of Mines and Geology Map Sheet 39, scale 1:1,000,000.

Roberts, C.T., 1985, Cenozoic evolution of the northwestern Honey Lake basin, Lassen County, California: Colorado School of Mines Quarterly, v. 80, no. 1, 64 p.

Russell, I.C., 1885, Geological history of Lake Lahontan, a Quaternary lake of northwestern Nevada: U.S. Geological Survey Monograph 11.

Toppozada, T.R., Real, C.R., and Parke, D.L., 1981, Preparation of isoseismal maps and summaries of reported effects for pre-1900 California earthquakes: California Division of Mines and Geology Open File Report 81-11, 182 p.

USDA, 1954, Aerial Photographs, Flight BUV, Numbers 10N 37-52, 12N 4-16, 93-99, 103-110, 13N 136-148, 15N 110-129, 16N 5-26, 59-81, 114-116, 17N 10-19, 148-176, 214-242, 18N 101-118, 122-136, 213-219, black and white, vertical, scale approximately 1:20,000.

USFS, 1982, Aerial Photographs, Flight 615110, Numbers 482 117-149, 179-203, 582 10-31, 56-74, 106-116, 145-147, color, vertical, scale approximately 1:30,000.

Wagner, D.L., Saucedo, G.J. and Grose, T.L.T., 1989, The Honey Lake fault zone, northeastern California, its nature, age and displacement (abstract): EOS, v. 70, no. 43, p. 1358.

Wilcox, R.E., 1965, Volcanic ash chronology: in Wright, H.E. Jr., and Frey D. G., editors The Quaternary of the United States, VII INQUA Congress: Princeton University Press, p. 807-815.

Photo 1. Surface rupture on the Fort Sage fault associated with the earthquake of December 14, 1950. Photo taken about three km north of Doyle on 1/27/51 by F.A. Riddell.

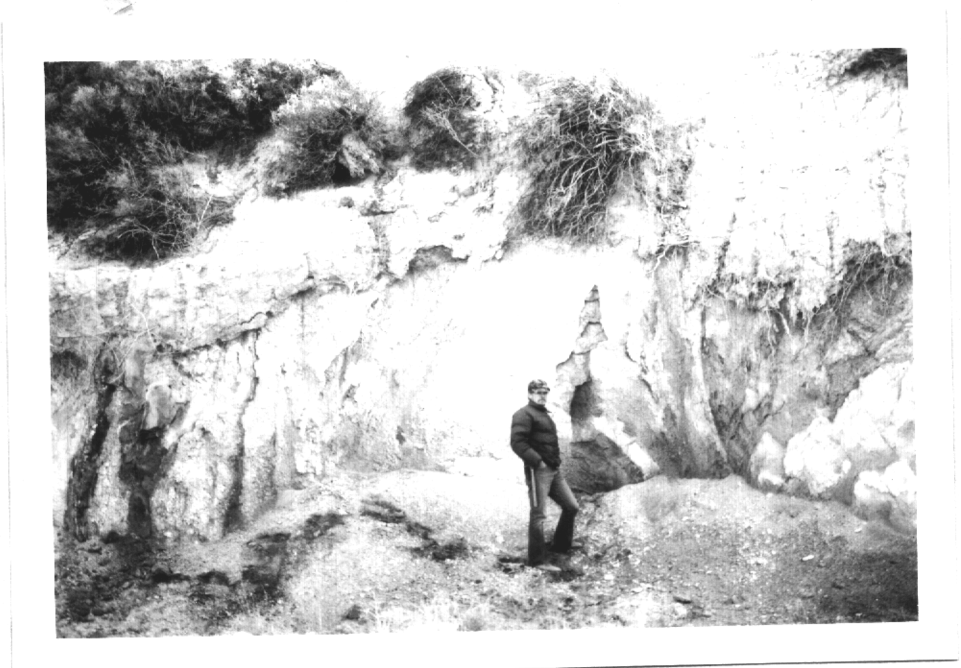
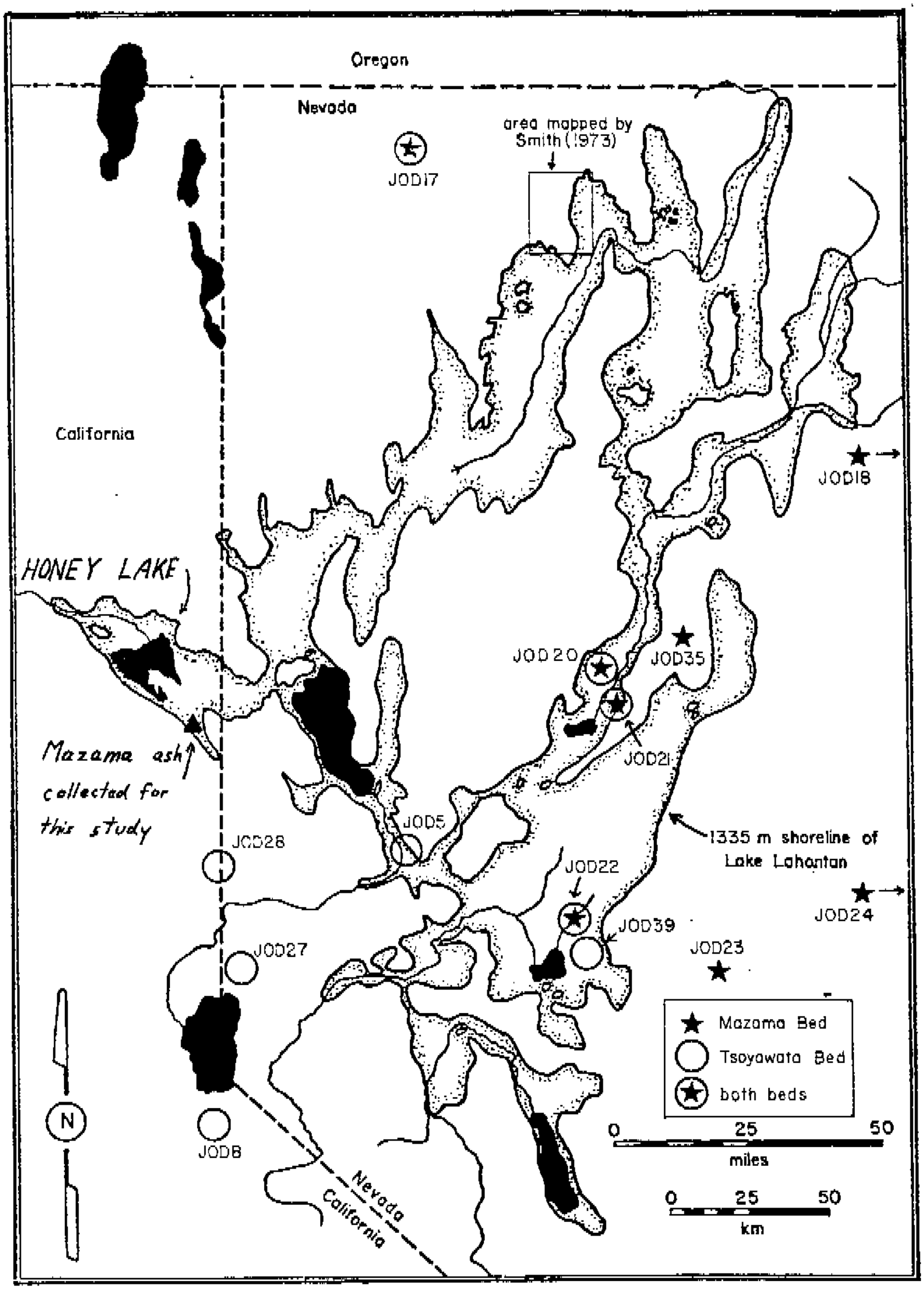
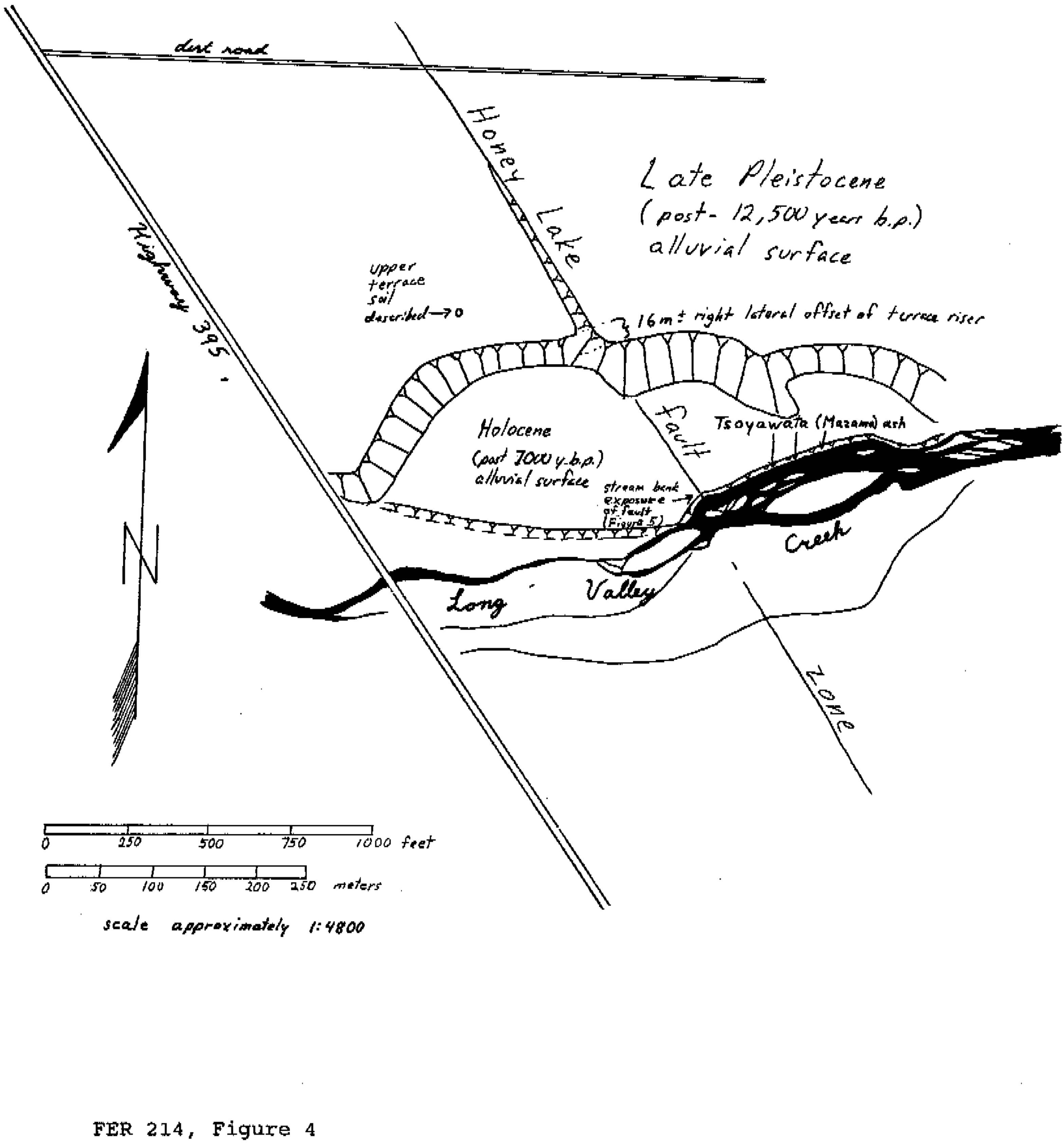


Photo 2. Exposure of Honey Lake fault zone at locality 10, (Figure 3b) dark area to right of man is loose dark gray sand injected along fault by liquefaction during an earthquake.




FER-214, Figure 2, Highest shorelines of Lake Lahontan (about 12,500 years old) and distribution of Mazama ash in the Lake Lahontan area. (modified from Davis, 1978)




FER 214, Figure 4

Sketch map of locality 7 (figure 3g) from 1954 aerial photographs, showing right lateral offset of Holocene terrace riser, location of stream bank exposure of fault zone and location of Tsoyawata ash sample.

**Appendix A.**

Descriptions of soils offset by the Honey Lake fault near Long Valley Creek, California (locality 7, Figure 3g, see figure 4 for a sketch map of this locality). Abbreviations and definitions are given in the key and in Soil Survey Staff (1951; 1975).

Upper terrace soil: described by G. Borchardt and C. Wills on November 15, 1989 at about 40° 3.20'north latitude 120° 7.47' west longitude and about 1280 (4200') elevation; east of U.S. Highway 395 near Doyle, CA. The landform is an old alluvial surface now isolated above the incised channel of Long Valley Creek. Arid climate with mean annual precipitation of 550 mm (Susanville) and mean annual temperature of 50.1°F (Susanville). Sage and other desert vegetation. Drainage good.

| Horizon | Depth, cm | Description |
|---|---|---|
| C? | 0 to 90 | yellowish brown to dark yellowish brown (10YR5/4d4/4m) sand; massive, non-sticky, non-plastic, sparse roots to 10 cm, moisture line at 40 cm. There is virtually no soil development at this location although this may be a "color b" (Bw) horizon. |

Southeast-facing stream bank exposure: described and sampled by G. Borchardt and C. J. Wills on June 21, 1990 at about 40°. 03.15'. north latitude, 120°. 07.47'. west longitude and ~1275 m (4180') elevation, east of U.S. Highway 395 near Doyle, CA. The landform is a younger inset terrace offset along the Honey Lake fault and currently being eroded by Long Valley Creek. Soil is formed on loamy Holocene stream alluvium overlying the Tsoyawata ash erupted from Mt. Mazama (Crater Lake, OR) at 7,015 B.P. Arid climate with mean annual precipitation of 550 mm (Susanville) and mean annual temperature of 50.1°F (Susanville). Sage and other desert vegetation. Slope 0.8 % southwest. Drainage good to seasonally fluctuating water table. Water table presently at 450 cm. Scientific classification: Cumulic Haplaquoll; fine silty, vermiculitic, non-acid, isomesic.

| Horizon | Depth, cm | Description |
|---|---|---|
| | | Station 5 (stations are in meters as shown on the log (Figure 5) |
| A | 0-10 | Dark grayish brown (10YR4/2m, 6/2d) coarse sandy loam; massive structure; non-sticky and non-plastic when wet, very friable when moist, and soft when dry; many very fine roots; few medium roots; many very fine constricted random vesicular pores; many vermiculite flakes; abrupt smooth boundary (Sample No. 90B006). |
| 2B | 10-16 | Very dark grayish brown (10YR3/2m, 4/2d) coarse sandy clay loam; medium strong angular blocky to coarse strong subangular blocky structure; sticky and very plastic when wet, friable when moist, and very hard when dry; many very fine and fine roots; many very fine and fine continuous random irregular and tubular pores; many vermiculite flakes; abrupt smooth boundary (Sample No. 90B007). |
| 2BC | 16-22 | Very dark grayish brown (10YR3/2m, 5/2d) coarse sandy clay loam; coarse moderate angular blocky to subangular blocky structure; slightly sticky and plastic when wet, friable when moist, and hard when dry; many very fine and fine roots; many very fine and fine continuous random irregular and tubular pores; many vermiculite flakes; abrupt smooth boundary (Sample No. 90B008). |

ESTIMATED AGE: $t_o$ = 400
$t_b$ = 0
$t_d$ = 400

| | | |
|---|---|---|
| 3Bb1 | 22-29 | Very dark grayish brown (10YR3/2m, 4/2d) heavy loam; medium moderate angular blocky to subangular blocky structure; very sticky and slightly plastic when wet, very friable when moist, and hard when dry; many very fine and fine roots; many very fine and fine continuous random irregular and tubular pores; many vermiculite flakes; clear smooth boundary (Sample No. 90B009). |
| 3Bkb1 | 29-51 | Dark brown (10YR3/3m, 5/3d) clay loam with many coarse to fine prominent white (10YR8/2md) mottles; coarse strong subangular blocky to angular blocky structure; sticky and slightly plastic when wet, very friable when moist, and very hard when dry; many very fine roots; many very fine and fine continuous and discontinuous random irregular and tubular pores; many vermiculite flakes; slight to violent effervescence with HCl; gradual smooth boundary (Sample No. 90B010). |

ESTIMATED AGE: $t_o$ = 1,500
$t_b$ = 400
$t_d$ = 1,100

| | | |
|---|---|---|
| 4Bk1b2 | 51-72 | Dark brown (10YR3/3m, 6/3d) sandy clay loam with many coarse to fine distinct white (10YR8/2md) mottles; coarse strong subangular blocky to angular blocky structure; sticky and slightly plastic when wet, very friable when moist, and very hard when dry; many very fine roots; many very fine and fine continuous and discontinuous random irregular and tubular pores; many vermiculite flakes; violent effervescence with HCl; abrupt wavy boundary; (Sample No. 90B011). |
| 4Bk2b2 | 72-78 | Dark brown (10YR3/3m, 6/3d) clay loam with many coarse to fine prominent white (10YR8/2md) mottles; coarse strong subangular blocky to angular blocky structure; sticky and plastic when wet, very friable when moist, and very hard when dry; common very fine roots; many very fine and fine |

continuous and discontinuous random irregular and tubular pores; many medium continuous random dendritic tubular pores; few thin discontinuous clay films on sand grains; many vermiculite flakes; violent effervescence with HCl; abrupt smooth boundary (Sample No. 90B012).

ESTIMATED AGE: $t_o$ = 2,700
$t_b$ = 1,500
$t_d$ = 1,200

5Bwk1b3 78-104 Dark brown (10YR3/3m, 6/3d) clay loam with many coarse to fine prominent white (10YR8/2md) mottles; coarse strong subangular blocky to angular blocky structure; slightly sticky and plastic when wet, very friable when moist, and very hard when dry; many very fine roots; many fine to medium continuous random dendritic tubular pores; rare charcoal fragments to 2 mm; many vermiculite flakes; violent effervescence with HCl; gradual wavy boundary (Sample No. 90B013).

5Bwk2b3 104-115 Dark brown (10YR3/3m, 6/3d) sandy clay loam with many coarse to fine prominent white (10YR8/2md) mottles; coarse strong subangular blocky to angular blocky structure; sticky and slightly plastic when wet, friable when moist, and very hard when dry; many very fine roots; common medium roots; many fine and common medium continuous random dendritic tubular pores; many vermiculite flakes; violent effervescence with HCl; gradual smooth boundary (Sample No. 90B014).

ESTIMATED AGE: $t_o$ = 4,200
$t_b$ = 2,700
$t_d$ = 1,500

6Bb4 115-123 Dark brown (10YR3/3m, 6/3d) fine gravelly coarse loamy sand; loose structure; non-sticky and non-plastic when wet, loose when moist, and loose when dry; common very fine to medium roots; many vermiculite flakes; few thin discontinuous clay films on sand grains; clear smooth boundary (Sample No. 90B015).

ESTIMATED AGE: $t_o$ = 4,800
$t_b$ = 4,200
$t_d$ = 600

| | | |
|---|---|---|
| 8Bb5 | 123-148 | Dark brown (10YR3/3m, 5/3d) clay loam; coarse strong subangular to angular blocky structure; sticky and plastic when wet, friable when moist, and hard when dry; many very fine to fine roots; common very fine to fine continuous random dendritic tubular pores; many vermiculite flakes; thin to moderately thick continuous clay films on sand grains, ped faces, and pores; carbonate filaments yield violent effervescence with HCl; abrupt smooth boundary (Sample No. 90B016). |
| 9Cb5 | 148-152 | Dark brown (10YR3/3m, 5/3d) gravelly sand; loose structure; non-sticky and non-plastic when wet, loose when moist, and loose when dry; few medium roots; many vermiculite flakes; carbonate coatings cementing sand grains to the bases of pebbles; the cement yields violent effervescence with HCl, but the sandy matrix does not; abrupt smooth boundary (Sample No. 90B017). |
| 10Cb5 | 152-163 | Dark brown (10YR3/3m, 5/3d) medium to coarse sand containing thin (~1 cm) black (10YR2/1md) silty units, particularly at its base; the silty units have manganese oxide coatings and common very fine random tubular pores coated with carbonate; loose structure; non-sticky and non-plastic when wet, loose when moist, and loose when dry; few medium roots; many vermiculite flakes; pore coatings yield violent effervescence with HCl; abrupt smooth boundary (Sample No. 90B018 [includes the 163-175 cm interval as well). |
| 11Cb5 | 163-175 | Dark brown (10YR3/3m, 5/3d) medium to coarse sand containing thin (~1 cm) black (10YR2/1md) silty units, particularly at its top; the silty units have manganese oxide coatings and common very fine random tubular pores coated with carbonate; massive to loose structure; non-sticky and non-plastic when wet, loose when moist, and loose when dry; many vermiculite flakes; pore coatings yield |

violent effervescence with HCl; abrupt smooth boundary (Sample No. 90B018 [includes the 152-163 cm interval as well).

ESTIMATED AGE: $t_o$ = 6,000
$t_b$ = 4,800
$t_d$ = 1,200

12Cb6 175+ Dark brown (10YR3/3m, 5/3d) coarse sand overlying loamy sand; massive to loose structure; non-sticky and non-plastic when wet, loose when moist, and loose when dry; many vermiculite flakes; few very fine roots; few fine pores in massive zones; abrupt smooth boundary at station 6.5 where this unit unconformably overlies the 13Bwb7 horizon (Sample No. 90B019 from an auger boring at station 2.5 where the unit is downward fining to fine sand at 287 cm).

ESTIMATED AGE: $t_o$ = 6,000
$t_b$ = 6,000
$t_d$ = 0

Station 5.6

7Bb4 86-100 Dark brown (10YR3/3m, 6/3d) clay loam; coarse strong angular blocky structure; slightly sticky and plastic when wet, friable when moist, and very hard when dry; few very fine to medium roots; common very fine and few medium continuous random dendritic tubular pores; many vermiculite flakes; gradual smooth boundary [the coarse sand at the base of this horizon probably correlates with the 6Bb4 horizon at station 5] (Sample No. 90B020).

ESTIMATED AGE: $t_o$ = 4,800
$t_b$ = 4,200
$t_d$ = 600

Station 7.7

13Bwb7k 72-98 Dark brown (10YR3/3m, 6/3d) silty clay loam; coarse strong angular blocky structure; sticky and plastic when wet, very friable

| | | |
|---|---|---|
| | | when moist, and hard when dry; many vermiculite flakes; few very fine roots; many very fine to fine continuous random dendritic tubular pores; filaments and nodular zones of carbonate; strong to violent effervescence with HCl; gradual smooth boundary (Sample No. 90B021). |
| 14Bb7k | 98-172 | Dark brown (10YR3/3m, 6/3d) loamy sand; massive structure; non-sticky and non-plastic when wet, loose when moist, and loose when dry; many vermiculite flakes; massive zones have common very fine to fine continuous random dendritic tubular pores; carbonate exists as filaments, as the cementing agent for massive zones, and as pore coatings; violent effervescence with HCl; gradual smooth boundary to Tsoyawata volcanic ash (7,015 B.P.) at station 26 [Level line at 92 cm corresponds to level line at 92 cm at station 5.] (Sample No. 90B022). |

ESTIMATED AGE: $t_o$ = 7,000
$t_b$ = 6,000
$t_d$ = 1,000

Station 26

| | | |
|---|---|---|
| A | 0-8 | Very dark grayish brown (10YR3/2m, 6/2d) sandy loam; massive structure; slightly sticky and slightly plastic when wet, very friable when moist, and soft when dry; many very fine roots; few medium roots; many very fine constricted random vesicular pores; many vermiculite flakes; abrupt smooth boundary (Sample No. 90B026). |
| 2B1 | 8-17 | Very dark grayish brown (10YR3/2m, 5/2d) clay loam; fine strong granular to coarse weak angular blocky structure; slightly sticky and slightly plastic when wet, very friable when moist, and soft when dry; many very fine roots; many very fine and fine continuous random irregular and tubular pores; many vermiculite flakes; clear smooth boundary (Sample No. 90B027). |

| | | |
|---|---|---|
| 2B2 | 17-42 | Dark brown (10YR3/3m, 6/2d) clay loam; coarse strong angular blocky structure; sticky and plastic when wet, very friable when moist, and hard when dry; many very fine roots; many very fine and fine continuous random irregular and tubular pores; many vermiculite flakes; clear wavy boundary (Sample No. 90B028). |
| 3B | 42-51 | Dark brown (10YR3/3m, 5/3d) loamy sand; coarse weak subangular blocky structure; slightly sticky and slightly plastic when wet, very friable when moist, and slightly hard when dry; common very fine to medium roots; many very fine and fine continuous random irregular and tubular pores; many vermiculite flakes; abrupt smooth boundary (Sample No. 90B029). |

ESTIMATED AGE: $t_o$ = 4,800
$t_b$ = 0
$t_d$ = 4,800

| | | |
|---|---|---|
| 8Bb5 | 51-72 | Dark brown (10YR3/3m, 5/3d) heavy loamy sand; coarse weak subangular blocky to coarse strong angular blocky structure; slightly sticky and slightly plastic when wet, very friable when moist, and slightly hard when dry; common very fine to medium roots; many very fine and fine continuous random irregular and tubular pores; many vermiculite flakes; carbonate as filaments and 3-mm nodules forming as coatings within pores have violent effervescence; clear smooth boundary (Sample No. 90B030). |
| 9-11Cb5 | 72-107 | Dark brown (10YR3/3m, 6/3d) thinly bedded units of fine gravelly coarse sand (72-76 cm and 88-90 cm), medium sand, and silt containing manganese oxide coatings on grains; loose to massive structure; non-sticky and non-plastic when wet, loose when moist, and loose when dry; silty units have common very fine to medium roots; silty units have many very fine and fine continuous random irregular and tubular pores; many vermiculite flakes; Sample 90B005 is charcoal fragment sampled at 90 cm; abrupt smooth boundary (Sample No. 90B031). |

ESTIMATED AGE: $t_o$ = 6,000
$t_b$ = 4,800
$t_d$ = 1,200

| | | |
|---|---|---|
| 13Bb7k | 107-145 | Dark brown (10YR3/3m, 6/3d) silty clay loam becoming loamy sand at the base of the horizon; coarse weak angular blocky structure; slightly sticky and slightly plastic when wet, very friable when moist, and soft when dry; many very fine and fine roots; many very fine to medium continuous random dendritic tubular pores; many vermiculite flakes; carbonate exists as common filaments and many 3-mm wide nodules forming in the shapes of vertical dendritic pores as much as 25 mm long have violent effervescence; Sample 90B004 is charcoal fragment sampled at 116 cm; gradual smooth boundary (Sample No. 90B032). |
| 14Bb7k | 145-162 | Dark brown (10YR3/3m, 6/3d) loamy sand; coarse weak angular blocky structure; non-sticky and non-plastic when wet, very friable when moist, and soft when dry; many vermiculite flakes; carbonate exists as few filaments and few 3-mm wide nodules having violent effervescence; gradual smooth boundary (Sample No. 90B033). |
| 15Cb7 | 162-178 | White (10YR7/2m, 8/2d) loamy sand (Tsoyawata volcanic ash, 7,015 B.P.); massive structure; non-sticky and non-plastic when wet, very friable when moist, and soft when dry; gradual smooth boundary (Sample No. 90B034, Sample No. 89B472 was collected from the 262-276 cm depth near station 66 on 11/14/89 for identification by Andrei Sarna-Wojcicki. Charcoal Sample No. 89B473 was collected 22 cm below the ash near station 48 on 11/14/89. Additional charcoal was found beneath the ash at station 39.5, but not sampled.) [Level line at 162 cm corresponds to the level line at 92 cm at station 5.] |

ESTIMATED AGE: $t_o$ = 7,000
$t_b$ = 6,000
$t_d$ = 1,000

*Pedochronology of the above soil or paleosol based on present knowledge. In the use of soils for dating purposes two dates and one duration are important:

$t_o$ = date when soil formation began, B.P.
$t_b$ = date when soil was buried, B.P.
$t_d$ = duration of soil development, yr

Table 1. Soils and paleosols offset along the Honey Lake fault ranked in decreasing order of pedological development*.

| Horizon | Thickness cm | Structure | Texture | Duration yr |
|---|---|---|---|---|
| | | Profile No. 1 | | |
| b3 | 37 | c3sbk-ank | cl | 1500 |
| b2 | 27 | c3sbk-ank | cl | 1200 |
| b5 | 25 | c3sbk-ank | cl | 1200 |
| b1 | 29 | m2ank-sbk | hl | 1100 |
| b7 (Sta. 7.7) | 26 | c3ank | sicl-ls | 1000 |
| b4 | 14 | c3ank | cl | 600 |
| 2B | 12 | m3ank-c3sbk | scl | 400 |
| b6 (Sta. 6.5) | 14 | 1 | s | 0 |
| Total allocated | | | | 7000 |
| Profile No. 2 | | | | |
| 2B | 43 | c3ank | cl | 4800 |
| b5 | 25 | c3sbk-ank | cl | 1200 |
| b7 | 38 | c1ank | sicl-ls | 1000 |
| Total allocator | | | | 7000 |

*In lieu of carbon dates, these particular pedochronological estimates were obtained by ranking the B horizons in decreasing order of development based on horizon thickness, structure, and texture. Durations were allocated assuming:

1. That the total allocable duration was 7,000 yr, the age of the underlying Tsoyawata ash.
2. That the b2 and b5 paleosols had equal development,
3. That the thickness of the b3 paleosol indicated it was proportionately older than the b2 and b5 paleosols.
4. That the m2ank-sbk structure of the hl b1 paleosol indicated it was slightly better developed than indicated by the c3ank structure of the sicl of b7 paleosol.
5. That the c3ank structure of the cl b4 paleosol indicated 50% longer development than the m3ank-c3sbk of the scl 2B soil in Soil Profile No. 1.
6. That the b6 paleosol had insignificant development.

Estimates have standard deviations of at least 15%.

Table 2. Pedochronology of soils and paleosols offset along the Honey Lake fault as derived from relative soil development.

| Soil or paleosol | $t_o$ B.P. | $t_b$ B.P. | $t_d$ yr |
|---|---|---|---|
| | Stations 3 through 8 | | |
| 2B | 400 | 0 | 400 |
| b1 | 1500 | 400 | 1100 |
| b2 | 2700 | 1500 | 1200 |
| b3 | 4200 | 2700 | 1500 |
| b4 | 4800 | 4200 | 600 |
| b5 | 6000 | 4800 | 1200 |
| b6 | 6000 | 6000 | 0 |
| b7 | 7000 | 6000 | 1000 |
| | Station 26 | | |
| 2B | 4800 | 0 | 4800 |
| b5 | 6000 | 4800 | 1200 |
| b7 | 7000 | 6000 | 1000 |